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Use of Interim Terrain Data to Populate Project 2351's Database in Support of Ground Forces Simulation

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Project 2851 is a Department of Defense (DoD) program to develop a standard DoD simulator database and associated transformation software necessary to support a wide range of simulator applications. Project 2851 is currently capable of directly inputting two standard Defense Mapping Agency (DMA) Digital Topographic Data (DTD) products, Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data (DFAD), to populate its simulator database. This report presents the findings from a study on the potential use of a third DMA DTD product, Interim Terrain Data (ITD), to populate Project 2851's database. ITD is compared to Project 2851's Standard Simulator database (SSDB) to determine the necessary transformation required to incorporate ITD into the SSDB. ITD is a high resolution standard terrain feature database product currently available to the Army; therefore, ITD should prove very useful to the simulation community especially for ground forces simulation applications.

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PREFACE

Under a Memorandum of Agreement (MOA), the U.S. Army Engineer Topographic Laboratories (ETL) Digital Concept and Analysis Center (DCAC) is providing technical support in the area of Mapping, Charting, and Geodesy (MC&G) to the Army Materiel Command's Project Manager for Training Devices (PM TRADE).

The author consulted with and received valuable input and comments from the following ETL Geographic Sciences Laboratory personnel: Mr. Douglas Caldwell, Mr. Mark Flood, Mr. John Hale, Mr. Richard Herrmann, Mr. Randall Karalus, and Mr. Kevin Muhm.

The work was performed during the period of June to October 1990 under the supervision of Mr. Juan Perez, Chief, Standards Branch, and Mr. Francis Capece, Director, Digital Concepts and Analysis Center.

Colonel David F. Maune, EN, was Commander and Director, and Mr. Walter E. Boge was Technical Director of the U.S. Army Engineer Topographic Laboratories during this report preparation.

USE OF INTERIM TERRAIN DATA TO POPULATE PROJECT 2851'S DATABASE IN SUPPORT OF GROUND FORCES

1. INTRODUCTION

1.1 Purpose

The purpose of this report is to describe Interim Terrain Data (ITD) for the Army simulation and training community and to present a study comparing ITD to Project 2851's Standard Simulator Database (SSDB).

1.2 Scope

First, this report provides a description of Project 2851 and an assessment of ITD. Specifically, the following ITD characteristics are presented: content, data resolution, accuracy, data density, minimum polygon size, and data storage requirements. Second, the report presents the results of a study comparing ITD to Project 2851/Rapidly Reconfigurable Data Base's (RRDB) SSDB. This study compares ITD's format, coding scheme, and data structure with the SSDB's format, coding schedule and structure.

1.3 Background

1.3.1 Standard DOD Simulator Digital Database/Common Transformation Program (Project 2851). Currently each simulator procured by the Department of Defense (DOD) has incorporated into its purchase price the cost of developing its own database and transformation program(s). This results in a proliferation of nonstandard, incompatible databases and software, which is costly for the Government in terms of both recurring development costs and maintenance costs.

Project 2851 is a tri-service program specifically designed to eliminate redundancy among DOD training simulator databases and transformation software. The objective for Project 2851 is to develop a standard DOD simulator database and the associated transformation software necessary to support a wide range of real-time Image Generation (IG) systems. This Standard Simulator Database (SSDB) will be designed with multiple Levels of Detail (LOD) (from 300 meters to 1 meter) resolution in support of various applications from high altitude flight simulation to ground forces simulation.

The Project 2851 Program will establish an operational facility, located at the Defense Mapping Agency Aerospace Center (DMAAC) in St. Louis, MO. This facility will function as a central repository for digital terrain elevation data, cultural feature data, and model data for use by the DOD simulation community.

1.3.2 Rapidly Reconfigurable Data Base (RRDB). The Rapidly Reconfigurable Data Base is an additional requirement levied on Project 2851 specifying the capability to rapidly generate a standard simulator database for mission rehearsal from a larger selection of data sources. The two primary tasks associated with RRDB are (1) to expand the type of input sources to Project 2851's SSDB to include various forms of imagery, and an option to include new DMA cartographic sources; and (2) to provide a photo-texture capability for both terrain and model data in support of newer, imagery-based training/rehearsal systems.

1.3.3 Interim Terrain Data (ITD). With the establishment of the RRDB initiative, a requirement was initiated to assess the utility of incorporating ITD into the SSDB to support ground forces training simulation requirements. Interim Terrain Data is a recently developed standard Defense Mapping Agency (DMA) Digital Topographic Data (DTD) product. The ITD product was originally designed to support the Army's near-term (1989-1993+) tactical and analysis requirements for DTD products.

Interim Terrain Data is an enhanced softcopy representation of the information portrayed on the 1:50,000 scale hardcopy Tactical Terrain Analysis Data Base (TTADB). Similarly, Planning Interim Terrain Data (PITD) is an enhanced softcopy representation of the information portrayed on the 1:250,000 scale hardcopy Planning Terrain Analysis Data Base (PTADB). A one-degree by one-degree Digital Terrain Elevation Data (DTED) level 1 cell is distributed with each ITD and each PITD cell.

ITD and PITD are currently being produced by two different methods; one method uses cartographic collection techniques, and the other method uses photogrammetric collection techniques. The cartographic method consists of digitizing each of the hardcopy Terrain Analysis (TTADB or PTADB) overlays. One of the overlays, the Transportation overlay, is enhanced with additional road features prior to digitization. Feature and attribute information is then encoded into the unsymbolized vector line data. The coding scheme employed is the Defense Mapping Agency Feature File (DMAFF).[1]

The photogrammetric method of producing ITD involves compiling ITD directly from stereo imagery source. All the features are collected and encoded with the appropriate DMAFF feature and attribute code information.

ITD is segregated into six thematic files. Three of the thematic files are "full areal coverage" feature files containing the following terrain information: surface configuration (slope), vegetation, and surface materials (soils). (The term "full areal coverage" thematic files indicates all of the area within these files' geographic bounds is classified with a slope, soils, or vegetation category.) The fourth thematic feature file contains surface drainage features; and the remaining two thematic feature files contain transportation and obstacles information.

ITD and PITD cells are sized to match the dimensions of the corresponding base maps. An ITD cell matches the dimensions of a 1:50,000 scale Topographic Line Map (TLM), and a PITD cell matches the dimensions of the 1:250,000 scale Joint Operation Graphic (JOG). ITD and PITD are distributed to users in DMA's Standard Linear Format (SLF).[2] ITD is currently available only on 9-track tape. However, the Army has stated a requirement for ITD on CD-ROM and DMA is currently investigating distributing ITD on this media in the future.

1.3.4 ETL's Participation in Project 2851/RRDB. Under a Memorandum of Agreement (MOA), the U.S. Army Engineer Topographic Laboratories (ETL) is supporting the Army Materiel Command's Project Manager for Training Devices (PM TRADE) with the development of database generation technologies, and the creation of several prototype databases. Under terms of the MOA, ETL is also scheduled to conduct information meetings and briefings between the participant government agencies and the prime 2851 contractor on data exchange formats, to provide terrain visualization demonstrations, and to provide reports pertaining to database development topics and studies. [3]

> [ETL's] Digital Concept and Analysis Center [DCAC] will work with PM TRADE and TRADOC personnel to assess the applicability of Interim Terrain Data (ITD) to meet the need of the Army training community for simulation of ground forces and to analyze the use of Project 2851 to meet these needs.

2. FINDINGS

2.1 Content

Interim Terrain Data and its related hardcopy source, TTADBs and PTADBs, were designed to support ground forces in tactical and planning applications. Since the terrain information contained in ITD was defined for ground forces applications, all of this information should be of value to the Army's ground forces simulation.

ITD contains detailed information on terrain and cultural features derived from extensive terrain analysis. Yet, specific Army simulation applications such as a tank simulator may require only a subset of the information contained in ITD. Also, low fidelity training simulators will be able to handle only a limited amount of the volume and content of information that ITD provides. However, almost every ITD feature and associated attribute(s) will be valuable to a specific simulation application. In addition, the robust information content of ITD will be particularly useful to fulfill the increased feature information content (features and attributes) requirements of next generation high fidelity simulators. Future applications will demand more information to enable them to more realistically depict the terrain. Therefore, Project 2851's SSDB must be capable of wholly accepting all of ITD's feature/attribute information.

Some ITD features and their attributes will not be modelled for most visual simulator applications partly because of limitations imposed by simulator hardware on: the amount of detail within its terrain database, the model complexity, and the number of models that can be visually displayed concurrently in "real-time."

In addition, many of the detailed attributes contained in ITD were derived specifically to generate synthesized terrain analysis products such as the cross-country movement and the concealment/areal detection products. Consequently, much of this detailed attribute information may not be visually significant enough to be modelled. For example, the following is a partial list of information that goes into the cross-country movement model:

> vegetation type, vegetation roughness factor, tree stem diameter, tree height and spacing, forest canopy closure, brushland and forest undergrowth density, ground surface material category, Unified Soil Classification System (USCS) soil type, soil roughness factor, soil moisture, soil depth, and slope gradient.

It is doubtful that most of this cross-country movement information will be modelled, but it could be used to generate texture, select coloring for terrain and models, or pattern spacing and density of models.

The ITD product contains primarily terrain features (i.e. soils, vegetation, drainage, natural obstacles, and slope gradient) with only a relatively small number of additional man-made feature types available to support transportation, hydrography, and man-made obstacles features. This product emphasizes features found outside of urban areas. The urban area polygon found on the soils, slope, and vegetation thematic files is basically "void collection area" polygon feature. Additionally, cultural features such as buildings, power-lines, commercial or industrial complexes are not collected for the ITD product. (The appendix contains a list of all ITD features categories by thematic file.)

In future investigations, DCAC personnel will examine ITD to determine its data content limitation. In particular, DCAC will examine ITD's limited ability to satisfy simulation data requirements for urban area features and other man-made features.

One of the most important content issues for utilizing ITD for ground forces simulation is how to properly use the information contained in the ITD database. Of particular concern is how these ITD terrain features are going to be appropriately filtered and thinned to match the data requirement of each individual simulator or suite of simulators.

One example of a method of reducing the volume of data in ITD would be to process the information pertaining to mobility from the ITD data sets into a single cross-country mobility polygon dataset in the generation of terrain databases to be used for tank simulation. This polygon information could be expressed as vehicle speed ranges or "GO", "SLOW", or "NO GO" areas. This generation of a tank mobility dataset would not preclude modelling features and their attributes from the surface material and vegetation overlays that have visually significant characteristics for tank simulation applications. For example, those features that serve as ground reference points, create visual obstructions, act as obstructions to mobility, affect concealment, or affect areal detection could still be modeiled.

2.2 Resolution

ITD is a vector database; therefore, no resolution statement exists for ITD. However, based on DCAC's knowledge about compilation methods and source materials used to create ITD, we estimate that the ITD product as a whole best fits into the SSDB's 30m Level of Details (LODs). The LODs stated for the SSDB are: 300m, 100m, 30m, 10m, and 1m. [4]

2.3 Accuracy

The Defense Mapping Agency (DMA), the DOD agency that has the primary responsibility for producing ITD, does not provide a numerical accuracy statement for ITD. The draft Military Specification for ITD (MIL-I-89014) states:

> The horizontal and vertical accuracy of the ITD will normally be no better than the base map to which the digitized hardcopy TTADB overlays were originally registered. These bases may be significantly less accurate than a 1:50,000 scale topographic [line] map [(TLM)].[6]

The majority of the TTADB products were produced by registering the six thematic overlays to a stable base positive of the 1:50,000 scale TLM. Therefore, a rough approximation of accuracy for ITD generated from a TTADB can be inferred from the horizontal accuracy of the TTADB basemap, the 1:50,000 TLM. The horizontal accuracy of the 1:50,000 scale TLM basemap, according to DMA, is roughly 50 meters. Consequently, ITD's horizontal accuracy is 50 meters for the majority of ITD cells generated from TTADB overlays.

Note: Accuracy for ITD is a complex issue. The method used to generate this estimated accuracy is extremely simplistic; therefore, any user of this information should exercise extreme care. This effort to provide a quantitative horizontal accuracy was made for the sole purpose of providing a "ball park" figure on the accuracy of ITD which would be useful to the Army simulator community. This information was helpful in determining which level of detail (LOD) ITD best fits within Project 2851's SSDB.

The horizontal accuracy will be higher for the ITD cells produced using photogrammetric methods. This higher accuracy is especially true for those features which are photo-identifiable and therefore may be visually significant. No information about the accuracy of ITD collected using photogrammetric methods is available at this time.

2.4 Data Density

Software was developed by ETL in order to be able to obtain data density information for ITD. This software was necessary in order to be able to calculate: the total lineal meters of vector data per ITD thematic file; and the number of features, segments, and nodes per ITD thematic file.

Data density information was generated for a ITD dataset located over the 1:50,000 scale Killeen TLM basemap in the vicinity of Fort Hood, Texas. The results are listed in Table 1. The greatest number of features for this dataset are found on the "full areal coverage" thematic feature files (slope, vegetation, soils) with an average of over 1,000 polygon features per file. This Killeen ITD dataset is not representative of a typical ITD dataset because it has a sparse road/railroad network and drainage pattern (low number of features, segments, and points.)

Further DCAC investigations are required in order to determine what the data density is for an average ITD cell

2.5 Minimum Polygon Size

Minimum polygon sizes in ground distance were calculated in order to provide further information about the maximum potential data density for ITD's soil, slope, vegetation, and surface drainage thematic feature files. For an ITD Surface Drainage feature file the minimum polygon size is defined to be 1 mm by 2 mm at map scale.[6] This equates to a ground size of approximately 50 m by 100 m. This means that theoretically, there is a maximum potential number of 132,000 polygons for a Surface Drainage feature file.

For all other ITD thematic files (Vegetation, Slope, Soils, and Transportation, and Obstacles) the minimum polygon size is 4 mm by 5 mm (or equivalent area) at map scale. This equates to approximately 200 m by 250 m on the ground (or roughly a 50,000 square meter area.)[6] Consequently, for vegetation, soils, and slope there is an upper limit of approximately 13,200 polygons per thematic feature file.

These maximum polygon counts for ITD feature files were calculated using the physical dimensions of the reference basemap. In reality, the polygon counts for any of these thematic feature files will be much lower than these maximum limits. Nevertheless, this information is useful as a comparison to the polygon counts for the Killeen ITD thematic feature files.

TABLE 1
KILLEEN/FT. HOOD ITD DATASET

Thematic Overlay	No. of Features	No. of Points	Aver. No. of Pts./Feat.	No. of Segments	Km of Vector Lines	No. of MB/File
SLOPE (A)	1,457	101,826	70	5,036	3,250	1.9
VEG. (A)	1,093	84,738	78	3,380	2,765	1.5
SOILS (A)	659	62,698	88	1,822	2,565	1.0
S.D. (A)	70		55			
S.D. (L)	703		13			
S.D. (P)	72		1			
total	845	26,366		1,665	921	0.6
TRANS. (L)	268		35	827		
TRANS. (P)	228		1	0		
total	496	9,726		827	616	0.3
OBS. (L)	137		11			
OBS. (A)	2		37			
total	139	3,382		139	122	0.1

SLOPE - Surface Configuration; VEG - Vegetation; SOILS - Surface Materials; S.D. - Surface Drainage; TRANS - Transportation; OBS. - Obstacles; (A) - Areal Features; (L) - Lineal Features; (P) - Point Features

Notes On Killeen Dataset:

The Killeen ITD Dataset, located in the vicinity of Fort Hood, Texas, covers approximately 660 square kilometers of ground area. This ITD Dataset was not compiled under the most recent ITD specifications. Therefore, the transportation overlay is much sparser than it would be if compiled under new specs. Approximately 84 square kilometers of the Killeen dataset were covered by "open water" and "built-up area" (64 square km of open water and 20 square km of built-up area). Therefore, this Killeen dataset had a reduced number of soils, slope, or vegetation polygons features in these thematic feature files.

2.6 Storage

DCAC was able to obtain information pertaining to ITD's storage requirements by developing software which could determine the file size for the six ITD thematic files on a 9-track tape. Storage information was generated for the six Killeen ITD files and the accompanying DTED. The storage requirements for each thematic feature file are listed in Table 1. The size of the six Killeen thematic feature files totals 5.4 Megabytes (MB). The size of the DTED Level 1 cell for Killeen is approximately 3 MB.

The Killeen ITD, as previously mentioned, is sparser than typical ITD. Hence this dataset's thematic feature files (vector format) have a lower than average storage requirement. Initial estimates for ITD storage range from 6 to 10 MB. (Typically, the size of vector data files will vary with the number of points used to digitize a feature and the density of features per feature file.)

DCAC personnel must examine a larger sampling of ITD cells in order to more precisely identify the range of files sizes for ITD.

All DTED Level 1 cells (raster format) from 0 degrees to 50 degrees latitude will have the same storage requirement of approximately 3 MB. At these latitudes, all DTED Level 1 cells have a matrix of 1201 posts by 1201 posts with 3 arcseconds post spacing (or roughly 100M post spacing.) At latitudes greater than 50 degrees, the size of the matrix is decreased resulting in smaller storage requirement.

The size of the DTED Level 1 matrix and consequently the storage requirement could be substantially reduced. For example, the DTED provided for the Killeen ITD covers a 1 degree by 1 degree area, whereas the Killeen ITD feature files covers a 15 minute by 15 minute area. Therefore, the size of the digital elevation matrix required to cover the Killeen ITD geographically could be reduced by a factor of sixteen from the original DTED Level 1 file.

2.7 Format and Coding Scheme

2.7.1 ITD Format. ITD is produced in Standard Linear Format (SLF) using the 17 November 1988 version of this format. SLF is a DMA digital cartographic feature data exchange format which uses a zero-overlap chain-node format for representing the spatial position of cartographic features. In a chain-node format, features are composed of digitized segments (chains of coordinate pairs.) A common boundary between two features is represented by only one shared segment, thus assuring that these features are precisely abutted. SLF stores the segments and provides the linkage (pointers) to concatenate them into features.[2]

2.7.2 SSDB Formats. The SSDB supports two formats for storing feature data within its Culture Data Files (CDF). One format is a chain-node structure which permits sharing of nodes and line segments among features. (According to the Project 2851 contractor, an internal SSDB chain-node format does exist but has not been implemented.) The other SSDB format for storing feature data is a polygonal format. As stated in SSDB documentation, this format "employs a polygon prioritization layering approach based on visual priority, similar to the approach used in the Digital Landmass System (DLMS) [DFAD's format], to handle stacked or overlapping features." No sharing of nodes and line segments is permitted for this format.

2.7.3 ITD Coding Scheme. ITD feature/attribute information is encoded using the Defense Mapping Agency Feature File (DMAFF) EIF 15034, Appendix 10.35, December 1983 coding scheme.[1] This coding scheme uses a hierarchical approach to encode the feature information. Each digitized feature has

associated with it a feature code. Each feature will also have one or more attributes associated with it, each containing a unique attribute value. The DMAFF coding scheme lists features using a five-digit alphanumeric (a/n) code, and attributes of features are listed by a three-digit a/n code. An attribute's value is defined by a numeric value which may range from 0 - 99998 for some attribute codes.

An example of a DMAFF Feature Code is "1F030" which defines a road feature. A road feature may have associated with it as many as 25 metric and descriptive attributes in the DMAFF coding scheme. These attributes define such things as: road Width (WDD) ranging in value from 0 to 500 decimeters; Road Surface Type (RST) with attribute values of 0 = unknown, 1 = hard/unpaved. 2 = loose/unpaved, 3 = loose/light, and 4 = corduroy; and Accuracy (ACC) with attribute values of 0 = unknown, 1 = accurate, 2 = approximate, 3 = doubtful, and 4 = juxtaposition.

2.7.4 SSDB Coding Scheme. The SSDB uses a feature coding scheme, called Feature Descriptor Code (FDC), which is similar to the five-character, hierarchical, alphanumeric feature codes established for DMA's Feature Attribute Coding System (FACS). FDC uses the FACS codes for features from the December 1988 version (E20-013) of DMA's Feature/Attribute Glossary. In addition, the FDC has incorporated Project 2851 specific feature categories not available in the FACS glossary. Every feature record has a FDC field (which identifies the type of feature), fields which defined common attributes, and a field for FACS attribute codes.[4]

2.7.5 Conversion of ITD into SSDB Format. The conversion of ITD in SLF to the SSDB chain-node format should require only a remapping of ITD records into the SSDB record format.

2.7.6 Conversion of ITD into the FDC Coding Scheme. Mapping ITD feature information from the DMAFF coding scheme to the SSDB's coding scheme will require the generation of a conversion look-up table. ITD DMAFF feature codes will map directly into an appropriate FDC code. Also, every ITD DMAFF attribute should map into either the common attribute field or into the SSDB FACS attribute field. Since the SSDB has the flexibility to add an indefinite number of new attribute fields without having to modify the database structure, ITD's attribute information should be easily inserted into the SSDB. Adding new FDC codes or modifying existing FDC feature codes may be necessary to incorporate vegetation and surface material features correctly into the SSDB. For example, the FDC does not contain the following FACS codes: 5E010 LAND USE/LAND COVER (majority of features in the Vegetation datafile), and 4A030 SURFICIAL MATERIALS (majority of features in the Surface Materials datafile).

2.8 Structure

The SSDB record structure appears to be similar to SLF structure. The structure of both SLF and SSDB has records containing attribute information, pointers from features to segments, FACS-like codes, list of segments, backpointers from segments to features, segment number, and a directed coordinate pair list. The structure of each differs but the information from ITD should easily map into the SSDB structure.

2.9 Datum and Cell Size

Both ITD and SSDB cells are referenced to the WGS 84 horizontal datum; the vertical datum is Mean Sea Level. Both ITD and SSDB feature data are positionally defined by latitude and longitude in two-dimensional space.

As previously mentioned, ITD cell size is determined by the dimensions of the 1:50,000 scale TLM from which the ITD cell is based. A TLM varies in size depending on the map series, the latitude of the map sheet, and other anomalies. The majority of ITD produced to date are 15 minutes by 15 minutes or 12 minutes by 20 minutes. Similarly, PITD cell size is defined by the dimensions of the 1:250,000 scale JOG from which the PITD cell is based. JOGs vary latitudinally from one degree by one degree near the equator to one degree by five degrees near the poles cells. The cell size for the PITD created over the Middle East is one degree by one degree 30 minutes.

The SSDB is managed in one degree by one degree units called cells. These cells are subdivided into manuscripts which are separate data files representing different forms of data and levels of detail (LOD). One of these SSDB manuscripts, called the culture data file, is where a cell of ITD information will map. The one degree by one degree DTED file that accompanies ITD will map directly into the SSDB terrain manuscript which is the same size.

2.10 ITD Area Coverage

Limited coverage of ITD is available for CONUS, Germany, Korea, and Saudi Arabia. PITD is available in limited coverage over Southwest Asia. Production of ITD started in 1989. To date there have been 160 cells of ITD produced over Germany, the Middle East, Korea, and the U.S. In addition, 24 cells of PITD have been produced over southwest Asia and the Middle East.

3.0 CONCLUSION

ITD is a "data rich" Digital Topographic Data product containing detailed terrain information. This information is valuable to the Army simulator community. Based on some rough estimates, ITD seems to best fit into the SSDB 30m LOD. The coding schemes and format of ITD is similar to that used in the SSDB. Consequently, a successful mapping of ITD into Project 2851's SSDB should not be difficult nor should a lengthy effort be required to create an ITD input program.

DCAC advocates having an ITD input capability to Project 2851's SSDB which would allow for the incorporation of the entire information content of ITD into the SSDB. ITD is a readily available standard product which will satisfy in part the Army's requirements for digital topographic data. Though the current area coverage for ITD is limited, production of this standard DMA product is planned well into the late 1990s.

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APPENDIX

Surface Materials Thematic File
ground surface (including soil category)
rock outcrop (& rock strata, rock formation)
snow field (& ice fields, ice caps)

Surface Configuration Thematic File
slope (% slope gradient category)

Vegetation Thematic File
bamboo (& wildcane)
brushland (& shrub, scrub)
cropland (cultivated)
grassland (& pasture, meadow)
marsh (& bog)
orchard (& plantation)
swamp (& mangrove)
trees (forest area)
vineyard (& hops)
wetlands (land subject to inundation)

Features that exist on Multiple Thematic Files
built-up area
ford (off-route & on-route)
miscellaneous graphic feature
open water (except inland)
void collection area

Surface Drainage Thematic File
aqueduct
canal (& channelized stream, drainage ditch)
dam
floating bridge (& raft site)
gorge
island
lock
river (& stream)

Transportation Thematic File
bridge
bridge span
cart track
constriction
drop gate (& drop gate road)
ferry crossing
railroad track
railroad passing (track)
railroad siding (track)

APPENDIX (Continued)

<u>Transportation Thematic File (cont'd)</u>
railroad yard
road
road radius curvature
runway (airfield)
tunnel (& tunnel entrance/exit)

<u>Obstacles Thematic File</u>
cut (road fill, railroad cut)
depression
dike (volcanic dike)
dragon teeth
embankment
escarpment (& bluff, cliff)
fill (road fill, railroad fill)
hedgerow
moat
pipeline
wall (& fence)
ramp (crossing ramp)

Note: The surface materials, configuration, and vegetation thematic files are used as input to the Cross-Country Mobility Model. These three thematic files are full area coverage datasets.

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